1981

Effects of Ground Sunflower Seeds in Diets of Late Gestating and Early Lactating Swine

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EFFECTS OF GROUND SUNFLOWER SEEDS IN DIETS OF LATE GESTATING AND EARLY LACTATING SWINE

BY

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A thesis submitted
in partial fulfillment of the requirements for the
degree Master of Science, Major in
Animal Science, South Dakota
State University
1981

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This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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ACKNOWLEDGMENTS

The author wishes to express his appreciation to his adviser, Dr. Richard C. Wahlstrom, for his cooperation and assistance during the course of these studies and his most helpful suggestions and criticisms during the preparation of this thesis.

Grateful acknowledgment is made to Dr. George W. Libal for his suggestions, advice and aid in the planning and conducting of my experiments and to my fellow graduate students for their advice and help throughout my study. I would also like to extend special thanks to Dr. Oscar Olson for his help in performing chemical analyses and to Dr. W. L. Tucker for conducting the statistical analysis of the data and for his assistance in the interpretation of the results.

The assistance of Miss Marjorie Thom for typing the final draft of this manuscript is also greatly appreciated.

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INTRODUCTION

In the production of swine, producers attempt to maximize profits. One of the ways profit may be increased is to increase the number of pigs weaned per sow, making that sow a more productive unit. Many advancements in this area have been made in the last 30 years. Environmental factors such as farrowing crates, supplemental heat sources for baby pigs and developing immunity in sows by exposure to disease organisms prior to farrowing combined with genetic selection for fecundity and mating management have resulted in more pigs per sow. Nutritional factors also have had an important impact in this area. Flushing and sow diet formulation for the proper balance of nutrients during gestation have proven to be effective in increasing number of pigs born.

Recently, a new means to increase the survivability of piglets has been investigated. This research involves the supplementation of fat into the diets of late gestating and early lactating sows to increase the energy stores in the newborn piglet and the energy that is available to these nursing piglets by increasing the fat content of the sow's milk. During parturition, piglets leave the uterus and are born into an environment that usually is 5 to 15 C less than uterine temperature. Piglets must then sever the umbilical attachment to the sow and begin nursing. Many times piglets are unable to accomplish this prior to depleting their energy reserves, becoming weak and highly vulnerable to sow overlay.

Limited amounts of energy in the piglet are available in the form of glycogen. Thus, by increasing glycogen stores, a newborn piglet may have a greater ability to find the udder, nurse and obtain a source of supplemental energy.

The fat content of the sow's diet can easily be increased by the inclusion of a high oil seed ingredient. Whole sunflower seeds fall into this category. Sunflowers are fast becoming a major agricultural crop in the United States and their usefulness as an ingredient in swine rations has not been established.

The objectives of this experiment were to determine:

1. The value of ground sunflower seeds as a part of the sow diet in late gestation and early lactation and their effect on (a) piglet birth weight, (b) piglet 14-day weight, (c) piglet 14-day weight gain, (d) piglet plasma blood glucose levels at birth and 24 hr of age, (e) sow weight change during lactation, (f) sow lactation feed consumption, (g) percent fat and fatty acid composition of sow's milk, and (h) piglet survivability.
2. Coefficients of apparent digestibility, digestible energy and nitrogen retention for rations containing 0, 25 and 50% ground sunflower seeds when fed to finishing swine.

REVIEW OF LITERATURE

Survival and Performance of Piglets

Causes of Baby Pig Mortality. The mortality rate of young swine is greater than the mortality rate of most other species. This can be attributed to various factors. Disease problems existing in herds may cause extensive death losses. However, in average farrowing situations, depleted energy levels of the piglet are the major cause of mortality as identified by several authors.

Hutchinson et al. (1954), utilizing 2116 piglets in 220 litters in four farrowing seasons, reported 25.9% of the pigs died postpartum. Of these, 23% died of inanition, 19% of inanition and congenital weakness, 15% were overlain, 5% died of congenital weakness and 5% of inanition and being overlain. The remaining pigs died of miscellaneous causes not related to a weakened state.

Bauman et al. (1966) used 1302 litters and reported an overall death rate of 13% of the live pigs born. They showed that inanition accounted for 25.8% and inanition and overlay for approximately 11% of the death loss. About two-thirds of the total death loss occurring in the first 3 days postpartum was associated with starvation.

Fahmy and Bernad (1971) investigated the causes of mortality for 6890 piglets born to Yorkshire sows. Of the live pigs born, 16.4% died by weaning, with 50% of these dying in the first 3 days following birth. Of those dying, congenital weakness and inanition (26.9%) and overlain or bitten by the dam (19.2%) were the major contributors. Only 18% of the pigs less than .45 kg survived to weaning.

Glycogen and Glucose in the Prenatal and Postnatal Pig. The development of the fetal pig is a curvilinear relationship with increasing age of the fetus (Ullrey et al., 1965; Brooks and Davis, 1969). There are major developmental changes in the composition of the fetal pig, with approximately one-third of the total body and liver weight gain occurring during the last 2 weeks of pregnancy. Fat, at birth, represents 1 to 2% of the total body weight. This body fat could theoretically supply 80 to 100 cal per kg body weight and furnish the basal energy requirements of the newborn pig of 50 to 100 cal per kg per day during 1 to 2 days of starvation. However, this fat is largely unavailable for mobilization due to much of it being in the structural state. What fat that can be mobilized is in the form of free fatty acids and they are quickly depleted in the starving pig (Gentz et al., 1970; Swiatek et al., 1968). In pigs that are allowed to nurse, free fatty acid levels rise rapidly following birth, a reflection of the milk intake, and continue to rise until 4 weeks of age (Bengtsson et al., 1969).

Glycogen is the major energy reserve of the newborn pig (Dawes and Shelley, 1968). Approximately 90% of the glycogen is found in the muscles of the carcass. The remaining 10% of the glycogen is in the liver in a greater concentration than found in the muscles. Small amounts of glycogen are also present in the heart, lungs and kidneys (Okai et al., 1978). Glycogen levels increase prior to birth, rising rapidly the last 4 weeks of gestation. Okai et al. (1978) found traces of glycogen in the liver as early as day 44 of gestation,

but it was not until day 68 that glycogen levels increased appreciably. Their results were similar to those observed by Mersmann et al. (1972) in which liver glycogen levels 10 days prior to birth doubled by 4 days before birth.

Following birth, glycogen is converted to glucose and is rapidly used up as the source of energy. Allowing glucose to fall to low levels results in a hypoglycemic coma and death. Curtis et al. (1964) measured liver glycogen and glucose in fasted pigs for 8 hr postpartum. Piglets were assigned to three groups: autopsied at birth, exposed to 30 C ambient temperature for 8.0 hr or exposed to 30 C ambient temperature for 7.5 hr followed by .5 hr of 4 to 8 C cold stress. Plasma glucose levels at birth were 80.0 mg per 100 milliliters. Glucose increased to 171 mg per 100 ml at 8.0 hr for those piglets exposed to 30 C ambient temperature as compared to 191 mg per 100 ml for piglets that were cold stressed. Glycogen to glucose mobilization was initiated and occurred mostly in the liver, followed by glycogen breakdown in the gluteus maximus muscle. There was no mobilization from the longissimus muscle except under cold stress when glucose mobilization was believed to occur to counter thermoinstability of the body.

Curtis et al. (1966) followed their previous research with a similar trial which showed plasma blood glucose concentration increased ($P<.01$) in pigs fasted from birth to 7.5 hr of age at 30 C ambient temperature. Cold stress of 4 to 8 C for .5 hr caused increased plasma glucose ($P<.05$), with mobilization from the liver and skeletal muscle reserves.

Trials conducted by Aherne et al. (1969) utilized piglets that were allowed to suckle at an ambient temperature of 28 C. Piglets had a linear ($P<.05$) increase (82 to 102 mg per 100 ml) in plasma glucose levels from birth to 12 hr, due probably to liver glycogen breakdown. This was followed by a curvilinear ($P<.01$) decrease (102 to 89 mg per 100 ml) over the following 36 hours. Blood plasma glucose levels at 24 hr were approximately 90 mg per 100 milliliters.

Seerley and Poole (1974) expanded their trials to include newborn piglets that were fasted or fed for 3 days. The concentration of glucose in the blood of 3-day fed animals was higher at 6.0 hr (104 mg per 100 ml) than at birth (63 mg per 100 ml) and remained relatively constant for the next 48 hours. Blood plasma glucose levels in 3-day fasted pigs, when compared to birth values, decreased after 24 hr from 59 to 53 mg per 100 milliliters. Blood plasma glucose was also significantly lower in fasted than in fed animals at 6, 24, 48 and 72 hours. Whole carcass glycogen levels (including liver), as a percent of total body weight, in the newborn, in 3-day fed and 3-day fasted piglets were 3.78, .65 and .53%, respectively.

Pettigrew et al. (1971) found blood plasma glucose levels more than doubled from birth to 2.0 hr, declined sharply to 8.0 hr and decreased more slowly to 32 hr with values of 60, 146, 119 and 86 mg per 100 ml, respectively. These values were similar to those previously discussed with the addition of a sample at 2.0 hr of age that had an even more rapid increase in plasma glucose level soon after birth. A positive correlation ($P<.05$) between 32-hr plasma glucose concentration

and 14-day weight was observed. Glucose concentration at birth was lowly correlated with 14-day weight.

Effect of Sow Feeding on Piglet Parameters. An attempt to influence the levels of glycogen in the newborn pig to reduce hypothermia through diet changes of the sow was conducted by Curtis et al. (1965). From the 99th day of gestation through farrowing, all sows received 1.36 kg per 100 kg body weight of a 15% crude protein diet once daily. Treated sows received, in addition, an oral glucose load of 150 g per 100 kg of body weight incorporated into the daily feed. Glycogen concentrations of the liver, longissimus and gluteus maximus muscles for pigs sacrificed immediately after birth were not found to be significantly different.

Anderson (1970) found that feeding gilts 2 kg per day of diets containing 15% sucrose or 15% prime yellow grease for 10 days prior to farrowing had no effect on liver or muscle glycogen of piglets when compared to a corn-soybean meal control diet. Liver glycogen level decreased ($P<.005$) from birth (15%) to 36 hr (2.9%) of age, indicating the importance of glycogen stores at birth as a source of glucose. Semitendinosus muscle glycogen also decreased from 9.1% at birth to 4.7% at 36 hr after birth. Even though muscle glycogen decreased in a manner similar to liver glycogen, the rate was not nearly as rapid (approximately an 80% decrease in liver glycogen compared to 50% for muscle glycogen). This substantiates liver glycogen as the immediate and rapidly available source of glucose at birth with muscle glycogen as a more sustained source of glucose. However, more overall glycogen

is available in the muscle when considering the relatively larger amounts present in the muscle than in the liver.

An experiment on the effects of the energy level of a sow's diet on the newborn pig was conducted by Buitrago et al. (1974). Energy levels of 2.2 and 8.0 Mcal of digestible energy per day were fed to gilts throughout gestation. Sucrose was added to increase the level of energy for the 8.0-Mcal diet. Both diets were balanced for crude protein, minerals and vitamins. The results showed that the average pig birth weight of the low energy dams was only 70% of the average birth weight of the offspring from the high energy dams (.76 vs 1.1 kg). Liver glycogen levels at birth strongly reflected the energy intake of the sows. Pigs from sows fed the low energy diet had lower ($P<.05$) liver glycogen levels (331 vs 2363 mg per 100 g). Blood plasma glucose at birth was not significantly different between treatments. The time of sampling in relation to birth was variable in this trial and may reflect some of these changes.

Elliot and Lodge (1977) used daily feed intake levels of .45 and 2.27 kg per sow to determine if short-term nutritional stress during late gestation affected the energy reserves or body composition of piglets at birth or during the early postnatal period of 96 hours. The diets were fed from day 100 of gestation and were formulated so that the intake of trace minerals and vitamins in both groups was the same. Liver glycogen levels at birth were significantly higher for piglets farrowed by the high intake sows than those of low intake sows. There was no significant difference in the levels of glycogen for the

gluteus maximus muscle at birth. Percentage of liver glycogen decreased approximately one-third during the first 6.0 hr postpartum and further decreased one-third more of the original value by 24 hr for both groups. Liver glycogen levels then increased from 24 to 96 hours. Decline of glycogen levels of the gluteus maximus muscle was continuous for the 96-hr period. Total fat content of the body increased two- to fourfold by 48 hr postpartum. Diet did not affect the birth weight of the piglets or body composition except for liver glycogen.

A similar experiment was performed by Ojamaa et al. (1980) in which .45 and 1.36 kg per day of a corn-soybean diet were fed from day 85 of gestation to farrowing. Restriction of feed reduced ($P<.05$) individual piglet birth weight, liver weight, skeletal muscle weight and liver and muscle glycogen concentration, showing that severe feed restriction during gestation had an effect on piglet energy reserves at birth.

Seerley et al. (1978a) experimented with the feeding of supplemental energy ingredients of corn starch or corn oil added to a basal diet to provide 24 Kcal of metabolizable energy (ME) per kg of body weight daily for 5 days prior to farrowing. Piglets born to these sows were either killed at birth, fasted for 3 days or fed for 3 days. Feeding the extra energy sources for 5 days prefarrowing did not result in any differences in percentage of glycogen or total lipids of the whole carcass at birth. Both fasted and fed piglets decreased ($P<.05$) in percent glycogen from birth to 3 days of age with no difference

between treatments. Total lipids increased in fed piglets due to the fat available in the milk. Piglets that were starved showed little decrease in percentage of carcass lipids, an indication of low utilization during starvation due to a poor ability to mobilize free fatty acids into the blood.

Two experiments were conducted by Boyd et al. (1978a). In one experiment, a control diet providing 5750 Kcal of ME per gilt daily was supplemented with either stabilized tallow or corn starch to provide 9300 Kcal ME per gilt daily from day 100 of gestation through farrowing. Piglet liver glycogen concentration was higher at birth for the tallow-fed gilts but not significantly different than the control or corn starch group. Piglet carcass lipid concentration at birth also was somewhat higher for the tallow-fed gilts. Glycogen in the liver was rapidly depleted postnatally; at 6.0 hr 49% of the glycogen remained and at 24 hr only 14% remained. Liver glycogen levels at 12 hr were 62, 98 and 59 mg per g of wet liver weight for piglets from control, tallow- and corn starch-fed gilts, respectively. Piglets from the tallow-fed gilts appeared to have more liver glycogen at birth through 12 hr in comparison to piglets from gilts in the other groups.

In the second experiment, 15% tallow was added to a control diet from day 109 of gestation to farrowing to observed glucose concentration. Piglets from dams fed tallow had a higher ($P<.10$) glucose concentration (54 vs 37 mg per 100 ml) at birth, 6.0 hr postpartum (89 vs 69, $P<.05$) and 24 hr postpartum (86 vs 67, $P<.05$) compared to the piglets born to control-fed dams.

Effect of Sow Diet on Survival and Performance of Piglets. An experiment on the effect of energy intake prior to farrowing on survival rate and energy stores available to the young piglet was performed by Seerley et al. (1974). Corn starch or corn oil was added to sow diets from the 109th day of pregnancy to farrowing. Piglet survival at 21 days was 90% for sows receiving corn oil, which was higher, although not significantly, than was observed for either the corn starch or control group. Piglets from dams fed corn oil that weighed less than 1 kg at birth showed a higher ($P<.05$) glucose level than those from dams fed the control and corn starch diets. Piglets from the two higher energy corn starch and corn oil treatments had a higher ($P<.05$) percentage of glycogen in the longissimus muscle than the controls. Corn starch and corn oil fed dams had piglets with higher levels of liver glycogen, but only the corn starch group was significantly higher. Cold stressing the piglets at 3 C for 90 min caused a greater increase in blood plasma glucose for the two high energy treatments than the control at 6.0 hr of age.

Wahlstrom and Libal (1976) fed a low energy diet of corn-soybean meal-dehydrated alfalfa meal and a high energy diet of corn-soybean meal-corn oil to sows and gilts the last 4 weeks of gestation and the first week of lactation. Animals fed the higher energy diet farrowed heavier pigs. The survival rate of pigs at 7 days was 90% from gilts fed the corn oil diet and 79% when gilts were fed the alfalfa meal diet. There was little difference between treatments in percent survival of piglets farrowed by sows or in growth rate of piglets to 7 days.

Cast et al. (1977) added 15% tallow to a control ration and found that tallow increased survival at 1 week ($P<.01$) and at 2 weeks ($P<.05$) as compared to the control diet. There was a slight increase in survival rate for those piglets born to tallow-fed dams weighing between .68 and 1.09 kilograms. Piglet blood plasma glucose levels analyzed at 1, 6 and 24 hr were higher, but not significantly, for offspring of the tallow-fed group.

Okai et al. (1977) found no significant difference in survival rate between piglets from sows fed a control diet at 2.0 kg per day or ad libitum or fed diets containing 10% added sucrose or 10% stabilized tallow ad libitum. All diets were fed from day 100 of gestation until farrowing. Survival rate of piglets weighing less than 1.0 kg was higher for the ad libitum control group. Three-week weaning weights of piglets from the sucrose treatment were higher ($P<.05$) than those from the sows fed tallow. Both groups had significantly higher weaning weights than the restricted or ad libitum fed controls.

Seerley et al. (1976) fed a control diet at 5 g per kg body weight with energy added as corn starch or lard at a level of 24 Kcal of ME per kg body weight from day 109 of gestation until piglets were weaned. They found no advantage in piglet survival due to energy sources. Survival of piglets that weighed less than 1.0 kg was higher (nonsignificant) for piglets from corn starch fed dams.

Research of Boyd et al. (1978a) utilizing the gestation diets cited previously plus lactation diets of a control and control plus 20% stabilized tallow fed for 14 days found lactation treatment did not

significantly affect survivability of piglets. Survival for those piglets weighing less than 1.0 kg for the first 3 days postpartum was not significantly different among the gestation treatments of control, stabilized tallow or corn starch addition, indicating no added energy benefit to the smaller pigs from the high energy diets being fed to their dams. Sows fed the lactation diet of added tallow had an increase in survival to weaning for piglets with birth weights less than 1 kg when compared to the control (53 vs 43%).

Parson (1979) incorporated 7.5 or 15% tallow or 15% of a tallow-vermiculite product (containing two-thirds tallow) into a control diet for sows for approximately 5 days prior to farrowing and fed these diets at a level of 2.5 kg per day or ad libitum following farrowing. Parson did not find any significant effect of dietary treatment on piglet survivability. However, survival of piglets from the dams fed the control diet was numerically less than that of the other treatments (81, 93, 90 and 88% for the control, 7.5 and 15% tallow and the 15% tallow-vermiculite, respectively).

Libal and Wahlstrom (1979) fed a corn-soybean meal-beet pulp diet or a control diet plus 10% yellow grease from day 106 of gestation through a 21-day lactation. They found no advantage in increased piglet birth or 21-day weights or in survivability of the piglets with the addition of extra fat.

Effect of Diet on Milk Lipids and Piglet Growth. During early postnatal growth, young piglets depend almost entirely on milk from the sow for their nourishment. The fat in the milk is a major source of

energy for piglet growth. Average lactation values for percent fat composition of sow's milk have been put forth by many authors with values as high as 10%. Colenbrander et al. (1967) measured fat levels in sows' milk for a 6-week period. The average percentage fat in colostrum and milk for weeks 1 through 6, respectively, were 5.8, 5.1, 5.4, 6.1, 6.1, 6.1 and 5.6. There was a drop in the level of fat for the 2-week period postfarrowing, followed by a rise to a plateau and then a decrease after 6 weeks.

Lodge (1959) found percent fat in milk to rise after farrowing with a peak at 3 weeks, followed by a steady decline with advancing lactation. Considerable individual variation from week to week was seen, with values ranging from 5 to 14% fat present in the milk.

Fahmy (1972) evaluated milk composition for several swine breeds and found the overall average fat content of milk to be 5.5, 6.5, 6.5 and 6.0% on days 1, 14, 28 and 35 of lactation, respectively. This shows an increase in fat level following the colostrum milk similar to the results of Colenbrander et al. (1967).

Many of the variations seen in milk fat percentage are due to dietary uptake of fat. The hydrolysis and resynthesis of triglycerides during the process of digestion and absorption in the monogastric produces similar but not identical triglyceride molecules in the lymph (Maynard et al., 1979). This is unlike the ruminant in which most of the lipids are fermented to volatile fatty acids, of which only acetate is used directly for the synthesis of milk fat. Based on dietary fat, high or low levels of triglycerides may be available in the sow's

blood to be utilized for milk, possibly influencing the level of fat in the milk.

Several authors have supplemented feeds with energy in the form of fats or carbohydrates. Friend (1974) fed two diets of a barley-wheat-soybean meal mixture which contained 10% corn starch or 10% corn oil from 5 days prior to farrowing through 35 days of lactation. The fat content of the colostrum from the corn starch fed-sows was lower ($P<.01$) than the subsequent samples taken weekly from the same corn starch fed-sows. Sows that received corn oil showed a slight but non-significant increase in milk fat content following the colostrum milk. Overall, the addition of corn oil to sow diets increased ($P<.01$) fat content of the milk over sows fed the control diet (9.4 vs 6.8%). This extra fat content resulted in faster gains to 21 days for piglets from corn oil-fed sows. Fatty acid analysis showed that the proportion of linoleic acid in the milk fat was higher ($P<.01$) when sows were fed corn oil.

Similar results were reported by Seerley et al. (1974) who fed a basal corn-oats-soybean meal diet, the basal diet plus corn oil and the basal diet plus corn starch from day 109 of gestation through farrowing. The feeding of corn oil increased ($P<.05$) total lipids in the colostrum milk with values of 5.5, 5.5 and 8.0 for the basal, corn starch and corn oil diets, respectively, with a numerical increase between corn starch and corn oil similar to that reported by Friend (1974). Colostrum linoleic acid was also increased ($P<.05$) by corn oil

addition, while percentages of palmitic, palmitoleic and oleic acid were reduced. Similar results were reported by Bertsch et al. (1967).

Miller et al. (1971) fed a corn-corn starch-soybean meal diet that was isonitrogenous and isocaloric to a 10% corn oil diet. The basal and corn oil diets contained 3 and 13% ether extract (dry matter basis), respectively. Milk samples in this study were collected at farrowing and 5 weeks thereafter. Average milk fat content during lactation was higher ($P<.01$) in the colostrum of the corn oil-fed sows. The feeding of corn oil increased ($P<.05$) the percentage of linoleic acid in both colostrum and lactation milk fat. The percentage of oleic acid decreased during lactation for sows fed both diets. Myristic, palmitic and palmitoleic acids increased for the control sows but did not change for the corn oil-fed sows. There was no difference in piglet weight gain to 5 weeks of age as a result of the diets.

A trial using soybean oil and corn starch as supplemental energy ingredients was conducted by Bishop et al. (1979). These authors fed sows from 9 days postpartum through 28 days of lactation and found soybean oil increased the fat percentage of the colostrum milk. Soybean oil appeared to have a similar effect on colostrum as corn oil supplementation seen in the other experiments cited here. Average pig weight was not affected by treatment.

Tallow and lard have also been used in the rations of sows to increase the fat content of milk. Okai et al. (1977) found 10% sucrose or 10% stabilized tallow in diets fed from day 100 of gestation did not affect ($P>.05$) fat content of the colostrum milk. Percentage of oleic

acid in the milk of the tallow group was higher ($P<.01$) than that found in the sucrose and an *ad libitum* control group. The feeding of the control diet at 2.0 kg per sow per day resulted in oleic acid levels similar to those for the tallow-fed sows. This suggests that restriction of energy intake or the addition of fat to the sow's diet would significantly influence the metabolism of fat in the body, allowing more oleic acid to be present in the milk.

Conflicting results were found by Boyd *et al.* (1978b) who reported tallow significantly increased colostrum levels of fat in sows fed additions of stabilized tallow. Administration of tallow immediately following farrowing increased ($P<.01$) milk fat during lactation. These authors also found no advantage to piglet growth by the addition of tallow during a 21-day lactation.

Results reported by Seerley *et al.* (1978b) support the work of Boyd *et al.* (1978b). Seerley and co-workers found colostrum and subsequent milk samples to be higher ($P<.01$) in total fat when feeding tallow-supplemented *vs* corn starch-supplemented diets. Milk from sows fed tallow was higher ($P<.05$) in oleic acid than milk from sows fed sucrose. Colostrum samples irrespective of diet treatment contained higher ($P<.05$) percentages of stearic and linoleic acids and less ($P<.05$) total lipids and palmitic and palmitoleic acids than milk samples collected on the third and sixth days after farrowing. Total lipids in milk increased equally in both dietary groups by the third day, but the milk from sows fed animal fat had approximately 2.5% more lipids than the control sows' milk.

Sunflower Seeds in the Ration of Swine

High oil sunflower seeds are a relatively new agricultural crop. Thus, limited research has been reported on the use of sunflower seeds as a feed ingredient in swine diets. Dinusson et al. (1980) added levels of 0, 2.5, 5.0 and 10.0% whole sunflower seeds to a barley-soybean meal diet fed to growing-finishing pigs. The sunflowers used analyzed 41% oil, 18.6% crude protein, 15% acid-detergent fiber and 3.6% ash. Average daily gains did not correlate to the levels of seeds used. Increasing levels of sunflowers in the diet did not result in significant changes in average daily gains, feed efficiency and feed intake. Results in these areas were variable and no trends could be seen. Visual inspection of slaughtered pigs showed no indication of high levels of unsaturated fatty acids in the tissues of sunflower-fed pigs.

Dinusson et al. (1981) substituted 13, 26 and 39% ground, whole sunflower seeds to a barley-soybean meal control diet fed to growing-finishing pigs. All diets were balanced to contain approximately 15% crude protein. An attempt was made to feed as a pellet, but the 26 and 39% diets would not hold their shape and were fed in an oily meal form. The higher levels of seeds (26 and 39%) resulted in decreased gains with the 39% level being significantly lower. Feed intake and feed efficiency varied among treatments but were not statistically different. The extra energy available from the sunflower seeds did not appear to be utilized as indicated by the identical feed efficiency of pigs fed the high sunflower seed and the control diet.

Ration Component Effect on Digestibility

Effect of Dietary Fat Level on Digestibility Coefficients.

The supplementation of moderate levels of fat to diets of pigs results in changes in the apparent digestibility of some nutrients. Lowrey et al. (1962) added 10% stabilized beef tallow to diets calculated to contain 10 and 18% crude protein. These diets were fed to growing pigs at a rate of 2.27 kg of feed per day. The apparent digestibility of the ether extract increased with the added fat from a level of approximately 55 to 83%. Fat did not affect the apparent digestibility of the crude protein or crude fiber.

Newman et al. (1967) also found levels of 10% added tallow increased ($P<.01$) the apparent digestibility of ether extract from 12% in a control diet to 70% for the added fat diet. Fiber digestibility was also increased ($P<.05$) from 15 to 33% for the control and fat-added diets, respectively. Apparent digestibility of crude protein and nitrogen-free extract was not affected by the addition of tallow.

Brooks (1967) added fat in the form of 10% soybean oil to a basal corn-soybean meal diet. The diets were fed ad libitum to growing pigs. Brooks found apparent digestibility of ether extract was increased ($P<.05$) when pigs were fed the 10% soybean oil diet. There was no effect on the apparent digestibility of crude protein, crude fiber, ash or nitrogen-free extract.

Results reported by Boenker et al. (1969) parallel those of Brooks (1967). Boenker and co-workers used growing pigs fed a control or 7% stabilized animal grease diet. Apparent ether extract digestibility

of the fat-added diet was higher ($P<.05$) than the corn-soybean meal control diet. Percent nitrogen retention did not differ between treatments, but pigs on the fat-added diets consumed less feed for a lower overall nitrogen retention. Kennelley and Aherne (1980) added 11.5% tallow to a barley-wheat-soybean meal diet and found the apparent ether extract digestibility of the tallow diet to be increased ($P<.01$) over the control diet. Crude fiber and dry matter digestion were decreased ($P<.05$) by the addition of tallow. Nitrogen retention was not affected.

Tribble et al. (1979) fed levels of 4 and 8% stabilized animal tallow to a control sorghum-soybean meal diet. Digestibility of the rations was determined with growing pigs at 41 and 73 kg body weight. The coefficients of digestibility by pigs at 41 kg for both protein and energy were greater ($P<.05$) for rations containing added fat, but no difference was found between fat levels. At 73 kg body weight, there were no differences in digestibility coefficients of protein and fat. Ether extract digestibility was not determined in this trial.

Effect of Dietary Crude Fiber Level on Digestibility Coefficients. The digestibility of crude fiber can vary from 0 to 90%, depending on the source of fiber, the level in the diet and total feed intake (Cunningham et al., 1962; Kass et al., 1980). Feeding diets that exceed 10% crude fiber has resulted in reduced coefficients of digestibility for crude fiber (Cunningham et al., 1962; Pollmann et al., 1979; Kass et al., 1980; Kennelley and Aherne, 1980), but little work has been

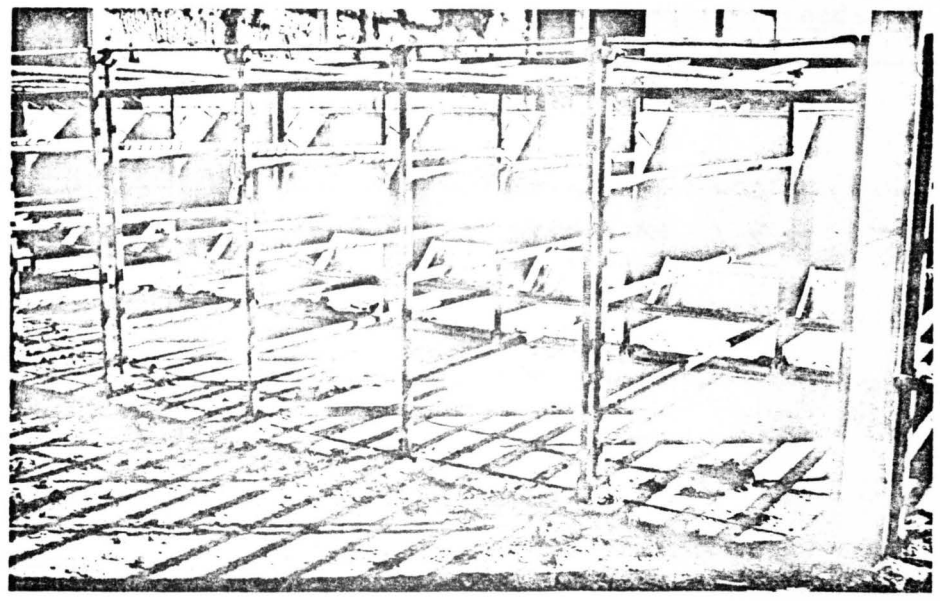
done on variations in crude fiber digestibility in diets containing less than 10% crude fiber.

It has been shown that additional crude fiber increases metabolic fecal nitrogen retention, causing a decrease in total nitrogen retention (Meyer, 1956; Whiting and Bezeau, 1958; Friend et al., 1963). This has been disputed by Kennelley and Aherne (1980) and Kass et al. (1980) who found no difference in nitrogen retention among pigs fed diets containing alfalfa meal at levels of 0, 20, 40 and 60%. Increasing the level of crude fiber will also decrease the apparent crude protein digestibility (Lloyd and Crampton, 1955; Whiting and Bezeau, 1958) and decrease dry matter digestibility (Kennelley and Aherne, 1980).

MATERIALS AND METHODS

Farrowing Trials

Fifty-five primparous crossbred gilts and 44 multiparous crossbred sows were used in three trials with farrowings occurring in March-April, June-July and August-September, 1980. These gilts and sows were kept in earthen lots, provided with shelter in the form of uninsulated, wooden frame houses and fed approximately 2.27 kg of feed per day until day 80 ± 10 days of gestation when they were placed in a cement lot with individual feeding stalls as shown in figure 1. At this time, sows and gilts were allotted into three treatment groups on the basis of weight, parity and breed of boar they had been bred to. Beginning on day 100 of gestation, treatment diets of 0, 25 and 50% ground, whole sunflower seeds were individually fed at a level of 2.27 kg per day until farrowing. Ingredient composition of the diets is shown in table 1. Nutrient composition of the whole sunflower seeds is shown in table 2 and of the diets in table 3. Due to the high oil content of the seeds, sunflowers were mixed with the corn prior to grinding. The feed was then stored in bins holding approximately 1 megagram located next to the gestation lot. Following farrowing, sows remained on their respective diets and were fed ad libitum through a 14-day lactation. All diets were calculated to contain 13% crude protein, .58% lysine, .70% phosphorus and .80% calcium. On day 110 of gestation, sows and gilts were moved to the farrowing house, washed with soap, rinsed with a disinfectant and allotted into individual crates or conventional farrowing pens with guard rails.



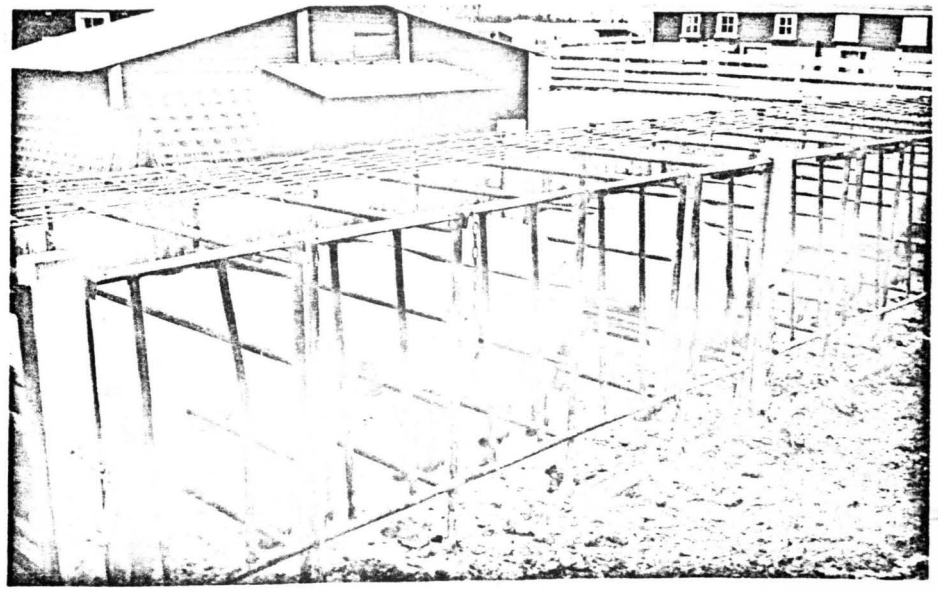


Figure 1. Individual feeding stalls.

TABLE 1. INGREDIENT COMPOSITION OF DIETS (%)

Ingredients	Sunflower seeds, %		
	0	25	50
Ground yellow corn	84.50	65.58	46.51
Ground sunflower seeds	0	25.0	50.0
Soybean meal, 44%	11.85	5.85	0
Dicalcium phosphate	2.27	1.89	1.54
Ground limestone	.75	.87	.97
Lysine	.03	.21	.38
Trace mineral salt[a]	.40	.40	.40
Vitamin-antibiotic mix[b]	.2	.2	.2

[a] .8% zinc.

[b] Supplied per kilogram of diet: vitamin A, 908 IU; vitamin D, 91 IU; vitamin E, 1.14 mg; riboflavin, .57 mg; pantothenic acid, 2.27 mg; niacin, 3.63 mg; choline, 11.4 mg; vitamin B_{12}, 2.27 mcg and aureomycin, 22.7 mg (trial 1); neomycin, 34.1 mg, and oxytetracycline, 34.1 mg (trials 2 and 3).

TABLE 2. CHEMICAL ANALYSES OF WHOLE SUNFLOWER SEEDS

Source	Percent
Moisture	8.81
Crude protein	17.3
Crude fiber	16.15
Ether extract	37.89
Ash	3.85
Calcium	.21
Phosphorus	.60
Amino acid	
Lysine	.64
Histidine	.42
Arginine	1.64
Aspartic acid	1.49
Threonine	.62
Serine	.77
Glutamic acid	3.97
Alanine	.48
Proline	.85
Glycine	.89
Cysteine	.23
Valine	.87
Methionine	.30
Isoleucine	.68
Leucine	1.05
Tyrosine	.36
Phenylalanine	.76

TABLE 3. NUTRIENT COMPOSITION OF DIETS (PERCENT)[a]

Source	Sunflower seeds, %		
	0	25	50
Moisture	10.70	8.90	8.11
Crude protein	12.75	12.64	12.67
Crude fiber	2.29	5.44	7.82
Ether extract	2.80	11.85	20.20
Ash	5.00	5.11	5.30
Nitrogen-free extract	66.44	56.06	46.58
Calcium	.83	.87	.87
Phosphorus	.75	.74	.72
Gross energy[b]	3911	4425	4793
Amino acid[c]			
Lysine	.59	.59	.46
Histidine	.39	.31	.30
Arginine	.78	.88	1.08
Aspartic acid	1.14	.97	.87
Threonine	.51	.47	.36
Serine	.65	.56	.48
Glutamic acid	2.41	2.12	2.58
Proline	.77	.67	.75
Glycine	.54	.59	.49
Alanine	.79	.76	.63
Cysteine	.24	.14	.18
Valine	.66	.63	.71
Methionine	.28	.28	.38
Isoleucine	.54	.52	.53
Leucine	1.40	1.16	1.18
Tyrosine	.58	.43	.46
Phenylalanine	.69	.55	.66

[a] Average of three separate samples of all diets.
[b] As determined by bomb calorimeter (kcal/kg).
[c] Dry matter basis.

In trial 1, one male and one female piglet were selected from each litter and bled at approximately 10 min following birth and prior to nursing. In trials 2 and 3, four piglets were selected at random disregarding sex and bled within 1 min following birth. Bleeding was performed by placing piglets in a "V" shaped trough, ventral side up. The head was held against the trough by twine and the front feet held caudal by the bleeder's hand. A 1 1/2-inch, 20 gauge needle on a disposable 1-ml syringe was inserted just cranial to the rib cage near the trachea and blood was removed from the vena cava by suction. All pigs were ear notched for later identification. Pigs bled at birth that were alive at 24 hr were rebled. Blood samples, taken from the vena cava, were deproteinated by a modified method of Nelson (1944). Blood was added to 5 ml of barium hydroxide, and 5 ml of zinc sulfate were then added and the mixture was centrifuged for 10 minutes. The supernatant was drawn off and frozen for later analysis. Plasma glucose was determined on the supernatant by the method of Somogyi (1945).

At birth, the number of live and stillborn pigs was recorded. General management practices of recording birth weights, clipping needle teeth, docking tails, iodining naval cords, notching ears and injection with 150 mg of iron dextran and 75 mg of tylosin were performed within 15 hr of birth. Piglets were reweighed at 14 days of age. Sows were weighed at day 110 of gestation, after farrowing and on day 14 of lactation. Daily feed consumption of sows during lactation was recorded. Milk samples were taken from each sow during farrowing and at 1 week and 2 weeks following farrowing by manual expression of the udder. Oxytocin

was administered intramuscularly at a level of 60 USP units per sow at farrowing and 100 USP units per sow for later milk samples to initiate milk letdown. Additional oxytocin was administered, as needed, to sows not letting milk down after the first injection. Potassium dichromate was added to the milk and the sample was refrigerated until analzyed. Milk was analyzed for fat content by the method of Mojonnier as outlined by Atherton and Newlander (1964). In trials 2 and 3, fat separated out by this method was stored at -10 C in petroleum ether. A sample of sunflower seed oil that had been extracted by AOAC (1975) procedures and composite milk fat samples from trials 2 and 3 were methalated by the procedure of Metcalfe et al. (1966) and analyzed in a Varian Aerograph 1440 gas chromatograph using a EGSS-X column for individual long chain fatty acid determination.

Digestion Trial

Six barrows averaging 66 kg were used in a digestion trial utilizing two 3 x 3 latin square designs involving three collection periods and diets containing 0, 25 and 50% whole ground sunflower seeds (table 1). Each of the three periods was divided into 5 days for adjustment to the diet followed by 5 days of total fecal and urine collection. Pigs were weighed at the beginning of the adjustment period and at the end of the collection period. Pigs were kept in rectangular, .6 by 1.5 meter digestion crates with expanded metal floors as shown in figure 2. Crates were housed in an environmentally controlled room at approximately 21 C. Feed was provided twice daily at a level that was

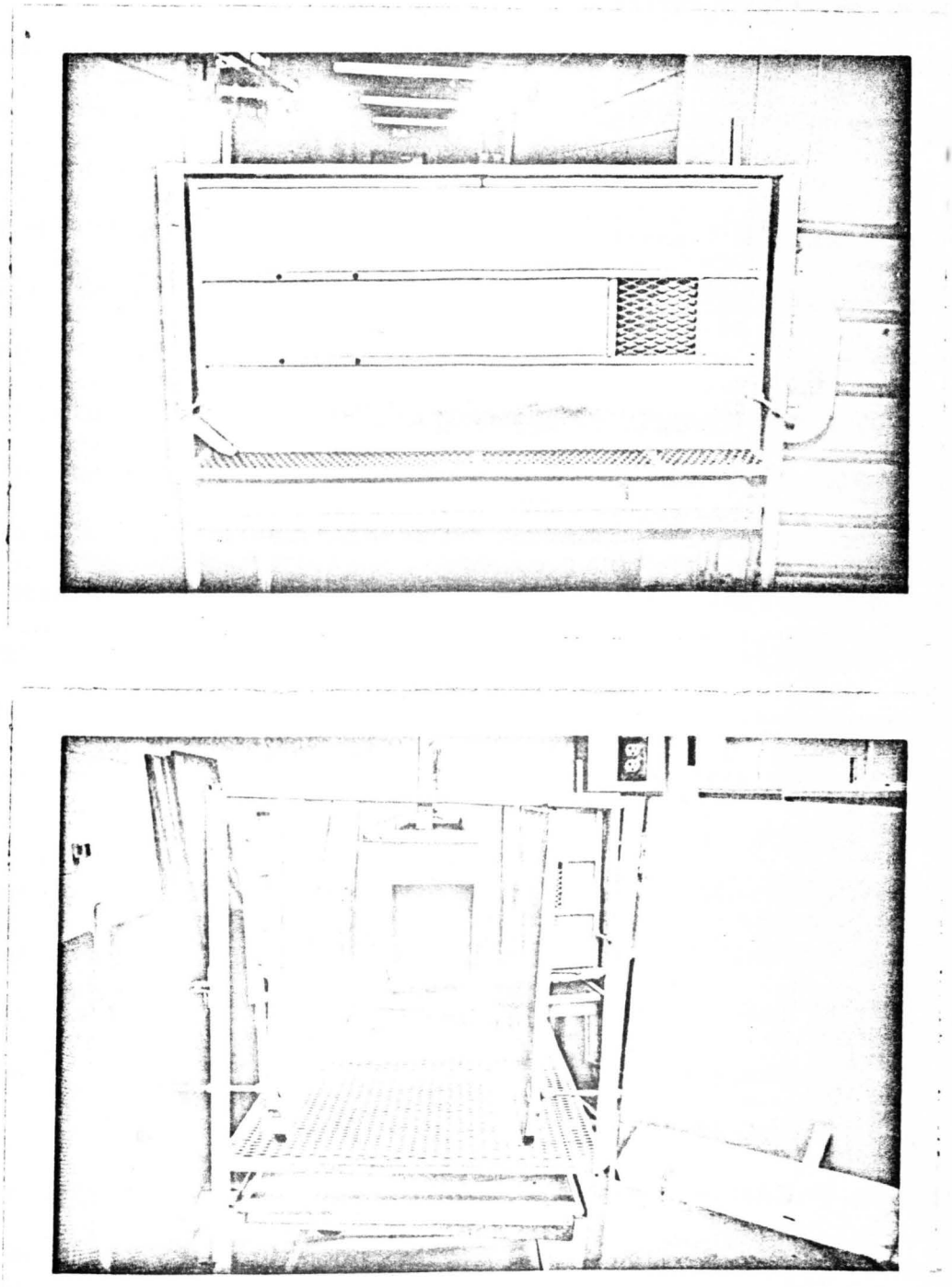


Figure 2. Digestion crates.

adjusted for consumption of the previous feeding. Water was supplied by addition to the feed. Orts were collected and added back into the feed twice daily. Feces were collected twice daily and frozen for later analysis at which time 5% by weight of the feces was dried in a 70 C oven for 48 hr for dry matter determination. Proximate analyses were performed on the dried feces by the AOAC (1975) procedures. Gross energy of feed and feces was determined using a Parr oxygen bomb calorimeter. Urine was collected in plastic jars to which 10 ml of 50% HCl had been added. Ten percent by volume of each day's urine output was combined and refrigerated until analyzed. Nitrogen concentration was determined on the urine by AOAC (1975) procedures. Digestible energy, percent nitrogen retention and apparent digestibility coefficients of dry matter, crude protein, energy, ether extract, nitrogen-free extract, organic matter and crude fiber were determined.

Statistical analyses were performed by least squares analysis of variance outlined by Steel and Torrie (1980). When significant differences were detected among treatment means, linear and quadratic components of variance were tested. A probability level of less than .05 was considered as the maximum level at which significance was accepted. Simple correlations were applied to birth weight, birth plasma glucose, 24-hour plasma glucose and 14-day weight of piglets bled at birth.

RESULTS AND DISCUSSION

Gestation-Lactation Trials

A summary of the effects of sunflower seed addition on performance of gilts and sows is presented in table 4. Analyses of variance for the data collected during these trials are reported in appendix tables 8 through 14. Data of three sows which refused to eat the 50% sunflower seed diet during gestation are omitted. Total number of farrowings for sows fed the 0, 25 and 50% diets were 35, 31 and 30, respectively. Two gilts and one sow in the control group, two sows fed the 25% sunflower diet and four sows fed the 50% sunflower diet developed mastitis after farrowing and have been omitted from the 14-day lactation data. There were no significant differences in mean 110-day gestation, postfarrowing and 14-day lactation weights, lactation weight loss and lactation feed consumption due to diets (table 4). Although consumption of diets did not vary significantly during lactation when initially fed at day 100 of gestation, several sows refused to consume the sunflower diets for 1 or 2 days. Following this adjustment period, consumption returned to normal. As stated previously, three sows refused to eat the 50% sunflower seed diet.

Significant trial and parity effects were observed for mean 110-day gestation, postfarrowing and 14-day lactation weights and 14-day lactation feed consumption. Significant trial effects for lactation weight loss were also observed. These data are shown in appendix table 1. Gilts, as expected, weighed less ($P<.05$) than sows in all trials. Average weights of sows and gilts combined varied ($P<.05$)

TABLE 4. LEAST SQUARES MEANS FOR 110-DAY GESTATION, POSTFARROWING AND 14-DAY LACTATION WEIGHTS, LACTATION WEIGHT LOSS AND LACTATION DAILY FEED CONSUMPTION

Item	Sunflower seeds, %		
	0	25	50
110-day gestation weight, kg	228.6	225.8	220.0
Postfarrowing weight, kg	210.7	209.5	205.2
14-day lactation weight, kg	210.5	203.5	200.1
Lactation weight loss, kg	2.7	5.9	4.1
Lactation daily feed consumption, kg	4.00	3.88	3.88

among trials, but there was no significant variation among treatments. Appendix table 2 shows significant trial by parity effects observed for lactation weight loss and lactation feed consumption. Gilts in trial 2 consumed less feed and lost more weight during lactation than sows and gilts in trials 1 and 3. Gilts consumed less ($P<.05$) feed than sows during lactation. Average lactation weight loss was greater ($P<.05$) in trial 3 than in trial 1, possibly due to the hotter weather in August and September, reduced feed consumption and a larger number of piglets weaned per litter (table 5) for those animals in trial 3.

The addition of sunflower seeds had no effect ($P<.05$) on the number of live piglets born, stillborn, number of piglets weaned or in percent survival (table 5). Trial and parity effects for number of live born and stillborn are summarized in appendix table 3. Trial and trial by treatment interactions for stillborns are presented in appendix table 4. Ether extract levels for the 0, 25 and 50% sunflower seed diets

TABLE 5. LEAST SQUARES MEANS FOR STILLBORNS, LIVE PIGS BORN, LIVE PIGS AT 14 DAYS AND PERCENT SURVIVAL

Item	Sunflower seeds, %		
	0	25	50
Stillborns	1.00	.85	.85
Live pigs born	9.77	10.09	9.33
Live pigs at 14 days	7.09	7.36	6.49
Percent survival	74.30	74.75	69.94

were 2.80, 11.85 and 20.20%, respectively. These were comparable to fat levels used in experiments of Seerley et al. (1976), Wahlstrom and Libal (1976), Cast et al. (1977), Okai et al. (1977), Libal and Wahlstrom (1979) and Parson (1979) in investigating additions of fat to the diets of gestating swine on survivability of piglets.

The least squares means for percent survival of piglets from sows fed 0, 25, and 50% sunflower seeds were 74.30, 74.75 and 69.94%, respectively. The decrease in percent survival of piglets from dams fed the 50% sunflower seed diet was not significant. Failure to achieve a significant increase in piglet survival due to fat supplementation and feeding diets high in fat content has also been reported by Seerley et al. (1974, 1976), Wahlstrom and Libal (1976), Okai et al. (1977), Boyd et al. (1978b), Libal and Wahlstrom (1979) and Parson (1979). However, Seerley et al. (1974) and Wahlstrom and Libal (1976) found a higher (nonsignificant) survival rate in piglets from sows fed added fat. Results reported by Cast et al. (1977) showed a significant increase in piglet survival when fat was added to the sow diets. In none of

these studies was piglet survival shown to be significantly reduced when sows were fed diets containing supplemental fat.

The percentages of fat in colostrum and 1- and 2-week milk samples are presented in table 6. There was a nonsignificant increase in fat levels of colostrum milk with addition of sunflowers to the sow diets. Colostrum milk fat percentages were 5.38, 6.41 and 6.61 for sows fed the 0, 25 and 50% sunflower seed diets, respectively. Extreme variation in colostrum milk fat percentages from 2.26 to 10.65, 2.01 to 16.87 and 2.99 to 9.68% for the 0, 25 and 50% sunflower seeds-fed sows, respectively, accounted for the failure to achieve significance. These results agreed with those of Okai et al. (1977) who found no significant difference in colostrum milk fat percentage when feeding stabilized tallow or a control diet. However, Miller et al. (1971), Friend (1974), Seerley et al. (1974, 1978b), Boyd et al. (1978b) and Bishop et al. (1979) have observed significant increases in colostrum milk fat due to additions of corn oil, soybean oil or tallow.

An analysis of milk samples at 1 and 2 weeks of lactation showed a linear increase ($P<.001$) in percent milk fat with increasing level of sunflower seeds. The increase in fat content agreed with the findings of Friend (1974), Boyd et al. (1978b) and Seerley et al. (1978b) who found postcolostrum milk to have a higher fat content when feeding diets high in fat. In all treatments, colostrum milk was lower in fat content than milk at 1 and 2 weeks of lactation. This increase was similar to the findings of Lodge (1959) and Fahmy (1972) and contrary to the findings of Colenbrander et al. (1967).

TABLE 6. LEAST SQUARES MEANS FOR COLOSTRUM, 1-WEEK AND 2-WEEK MILK FAT PERCENTAGE

Item	Sunflower seeds, %		
	0	25	50
Colostrum milk fat, %	5.38	6.41	6.61
1-week milk fat, %[a]	7.83	10.09	11.42
2-week milk fat, %[a]	7.61	9.42	11.72

[a] Linear effect ($P<.001$).

The average fatty acid composition of composite milk samples from sows in trials 2 and 3 and the fatty acid composition of the ether extract portion of the sunflower seeds used are shown in table 7. Although the data were not analyzed statistically, trends can be seen in the data for variation due to increasing levels of sunflower seeds. Sunflower seeds are high in linoleic acid (69% of the total fatty acids). With increasing levels of sunflower seeds in the diet, linoleic acid in the milk increased. Milk from the sows fed 50% sunflower seeds contained more than twice as much linoleic acid as milk from the control sows for all times sampled. The increase in levels of linoleic acid was in agreement with the findings of Miller et al. (1971), Friend (1974) and Seerley et al. (1974) when supplementing corn oil to the diets of lactating sows. A trend in the research reported herein for linoleic acid to be higher in colostrum milk than in subsequent milk can be noted. Myristic and palmitoleic acids are not found in sunflower oil and palmitic acid is found in low amounts. With increasing levels of sunflower seeds, myristic, palmitic and palmitoleic acids decreased

TABLE 7. TIME BY TREATMENT FATTY ACID COMPOSITION OF SOWS' MILK[a] AND COMPOSITION OF SUNFLOWER SEED OIL

Time of sampling	Percent sunflower seeds	Percent fatty acid[b]					
		Myristic (C14:0)	Palmitic (C16:0)	Palmitoleic (C16:1)	Stearic (C18:0)	Oleic (C18:1)	Linoleic (C18:2)
Farrowing	0	4.9	29.0	5.5	5.4	29.4	25.8
	25	3.6	28.8	3.7	4.0	20.8	39.1
	50	1.5	20.5	2.0	4.8	21.2	50.0
1 week	0	5.8	35.3	11.4	4.1	29.5	13.9
	25	7.3	30.8	5.8	3.7	20.0	32.4
	50	3.3	25.6	3.2	4.2	22.0	41.7
2 weeks	0	4.4	34.9	11.9	4.0	24.8	20.0
	25	6.1	28.1	4.3	3.2	18.6	39.5
	50	3.9	24.2	2.5	4.1	20.5	44.8
Sunflower seed oil		0	7.5	0	4.5	19.0	69.0

[a] Values represent the average of trials 1 and 2 composite milk samples.
[b] Values are expressed as a percentage of total fatty acid composition.

in the milk over all time periods. Seerley et al. (1974) reported lower levels of palmitic and palmitoleic acids with the addition of corn oil. Trends for myristic, palmitic and palmitoleic acids to increase in the milk of control sows with advancing lactation were similar to the findings of Miller et al. (1971).

Least squares means for litter and piglet birth weights, 14-day weight and 14-day weight gain are summarized in table 8. There were no effects in any of the criteria due to the addition of sunflower seeds to the diets. The higher fat and thus the increased energy content of milk from sows fed sunflower seeds did not result in increased gain of the piglets. Variable results have been found in milk fat effects on piglet growth. Wolfe et al. (1977) found that higher levels of butterfat in semi-purified liquid diets fed to piglets increased 14-day weight gain. Boyd et al. (1978b), Bishop et al. (1979) and Libal and Wahlstrom (1979) did not find any advantage in increased birth and weaning weights of those piglets whose dams had been fed added fat diets. Friend (1974) found weight gain to increase in piglets when sows were fed corn oil-supplemented diets compared to weights of piglets from sows fed diets without supplemental fat. Okai et al. (1977) showed tallow additions to the dams' diets increased weaning weight of piglets.

Significant parity differences were observed in litter birth weight, with gilts having lower litter birth weights than sows. Sows in trial 1 had significantly lower litter birth weights than those in trial 3. There was a 2.4 pig increase in number of live born for those

TABLE 8. TREATMENT LEAST SQUARES MEANS FOR LITTER AND PIGLET BIRTH WEIGHT, 14-DAY WEIGHT AND 14-DAY WEIGHT GAIN

Item[a]	Sunflower seeds, %		
	0	25	50
Litter birth weight	14,025	14,157	13,579
Piglet birth weight	1,458	1,415	1,478
Litter 14-day weight	25,808	27,096	23,269
Piglet 14-day weight	3,648	3,637	3,772
Litter weight gain to 14 days	15,055	16,321	13,400
Piglet weight gain to 14 days	2,143	2,181	2,158

[a] All weights are in grams.

litters in trial 3 over trial 1. Krider and Carroll (1971) suggested pig birth weights decrease as litter size increases.

Plasma glucose at birth and 24 hr of age was not significantly different among treatments (table 9). This conflicts with results reported by Boyd et al. (1978a), who found plasma glucose levels at birth and 24 hr of age to be higher for those piglets whose dams had been fed a diet containing 15% tallow. However, Cast et al. (1977) reported a nonsignificant increase in plasma glucose at birth and 24 hr for piglets from dams fed tallow.

Plasma glucose values at birth are not reflective of liver glycogen levels. Boyd et al. (1978a) conducted a study that was divided into two separate experiments. In the first experiment, these authors measured plasma glucose levels and found the concentration to be higher at birth for piglets from tallow-fed dams than for sows fed a

TABLE 9. TREATMENT LEAST SQUARES MEANS FOR BIRTH AND 24-HR PLASMA GLUCOSE AND BIRTH AND 14-DAY WEIGHTS

Item	Sunflower seeds, %		
	0	25	50
Number of piglets[a]	115	96	106
Avg birth weight, g	1,477	1,508	1,517
Avg birth plasma glucose, mg/100 ml	93.5	93.1	90.2
Avg 24-hr plasma glucose, mg/100 ml[b]	83.6	84.6	78.9
Avg 14-day weight, g	3,652	3,767	3,425

[a] Trial 1 - two pigs per sow, trial 2 - an attempt was made to get four pigs per sow and trial 3 - four pigs per sow.
[b] Not all pigs bled at birth survived to 24 hours.

corn-soybean meal control diet. In the second experiment, liver glycogen levels were higher, but not significantly, at birth for the tallow-fed group. Rations for both experiments were the same. These experiments were separate and it cannot be stated that higher glucose values represent higher liver glycogen levels because the two were not measured together in the same experiment. This leaves some question as to the value of birth plasma glucose concentration as a measurement of glycogen stores and of the energy available to the piglet.

Liver glycogen concentration of the piglets on each treatment in the experiment reported herein was not determined, but glucose values at birth were not different. Values for 24-hr plasma glucose would be more reflective of the glycogen stores. Curtis et al. (1966) and Seerley and Poole (1974) have found glucose levels of glycogen-depleted

piglets to be extremely low. This glycogen depletion occurs by 24 hr of age. In the experiment reported herein, 24-hr plasma glucose levels did not differ among treatments, indicating approximately the same amount of glycogen stores among treatments at 24 hr of age. This was contrary to the results of Boyd et al. (1978a).

Several authors (Buitrago et al., 1974; Elliot and Lodge, 1977; Ojamaa et al., 1980) have found that dams fed diets restricted in energy produced piglets at birth with significantly less liver glycogen levels. However, liver glycogen levels have not been found to be significantly increased by the addition of supplemental fat to a diet adequate in energy. Boyd et al. (1978a) found higher (nonsignificant) liver glycogen levels in newborn piglets when their dams were fed a tallow-added diet versus an isocaloric control diet formulated to provide adequate amounts of energy. Anderson (1970) observed no difference in liver glycogen level of newborn piglets due to dams being fed high-energy rations containing fat or sucrose.

Table 10 shows correlation coefficients between plasma glucose concentration at birth and 24 hr and for birth weight and 14-day weight for those piglets bled. Birth plasma glucose values were correlated ($P<.01$) with 24-hr plasma glucose values ($R = .19$). Although significantly correlated, only 3.6% of the variation in 24-hr plasma glucose can be accounted for by birth plasma glucose ($R^2 = .036$). Thus, birth plasma glucose is a questionable indicator of 24-hr plasma glucose. Birth weight had a higher correlation ($R = .33$, $P<.01$) with 24-hr plasma glucose than did birth plasma glucose. Fourteen-day weights were

TABLE 10. CORRELATION COEFFICIENTS FOR PLASMA BLOOD GLUCOSE AT BIRTH AND 24 HR AND BIRTH WEIGHT AND 14-DAY WEIGHT

Item	Birth glucose	24-hr glucose	Birth weight	14-day weight
Birth glucose	1.00	.19[a]	.11	.02
24-hr glucose		1.00	.33[a]	.26[a]
Birth weight			1.00	.34[a]
14-day weight				1.00

[a] P<.01.

correlated (P<.01) with 24-hr plasma glucose and birth weight (R = .26 and .34, respectively).

An analysis of variance was performed using plasma glucose at birth and 24 hr as dependent variables on piglet survival to 14 days. Table 11 lists the least squares means for these data. Plasma glucose concentration at birth had no effect on survival to 14 days. Twenty-four-hr plasma glucose values were higher (89.4 vs 63.5 mg/100 ml, P<.01) for those piglets living to 14 days than those piglets that died during this period. Therefore, plasma glucose concentration at 24 hr seemed to be a more accurate indicator of survivability of a piglet than plasma glucose at birth.

Although piglets bled at birth were chosen at random, there was no significant difference in weight of these piglets among treatments. Likewise, there were no differences in weights at 14 days of age. Trial effects for plasma glucose at birth can be seen in appendix table 6. Trial 1 piglets had significantly higher plasma glucose levels than

TABLE 11. LEAST SQUARES MEANS OF BIRTH AND 24-HR PLASMA GLUCOSE BY LIFE STATUS AT 14 DAYS POSTFARROWING

Item	Status 14 days postfarrowing	
	Live	Dead
Birth glucose, mg/100 ml	90.3	88.8
24-hr glucose, mg/100 ml[a]	89.4	63.5

[a] $P<.01$.

trial 3 piglets. One possible explanation of the higher glucose values for trial 1 piglets would be those piglets were not bled until approximately 10 min after birth in contrast to trial 3 piglets that were bled within 1 min of birth. At 10 min of age, piglets from trial 1 may have begun an increase in blood glucose concentration as has been described by Pettigrew et al. (1971), who found blood plasma glucose levels more than doubled from birth to 2.0 hours.

Digestion Trial

Table 12 shows the coefficients of apparent digestibility of the proximal constituents and energy of the diets and also the percent nitrogen retained and digestible energy values for all diets. Analysis of variance of these criteria are reported in appendix table 15. Table 3 shows the composition of the dietary constituents. Of the six pigs used in this study, one pig became ill during the first trial and remained ill for all three trials. Data for this pig were omitted from the results. There was no significant difference among diets in feed consumption. Therefore, no difference in digestibility coefficients

TABLE 12. LEAST SQUARES MEANS FOR COEFFICIENTS OF APPARENT DIGESTIBILITY OF THE PROXIMAL CONSTITUENTS AND ENERGY, PERCENT NITROGEN RETENTION AND DIGESTIBLE ENERGY OF THE DIETS

Item	Sunflower seeds, %		
	0	25	50
Dry matter[c]	82.7	80.3	73.3
Crude protein	77.9	78.5	74.9
Energy[b]	81.6	79.1	72.7
Ether extract[d]	20.6	64.9	68.1
Nitrogen-free extract[d]	89.7	89.3	84.9
Organic matter[c]	84.4	81.5	74.2
Crude fiber[c]	24.1	31.5	15.3
Nitrogen retention, %	42.1	43.8	38.3
Digestible energy, kcal/kg[a,e]	3192	3499	3486

[a] Linear effect (P<.05).
[b] Linear effect (P<.01).
[c] Linear and quadratic effect (P<.05).
[d] Linear and quadratic effect (P<.01).
[e] Dry basis.

can be attributed to variation in feed consumption. Significant trial effects for dry matter, nitrogen-free extract and crude fiber digestibilities are summarized in appendix table 7.

Apparent Digestibility of Gross Energy and Digestible Energy. The coefficients of apparent digestibility for energy decreased linearly (P<.01) from 81.6 to 79.1 and 72.7% for 0, 25 and 50% sunflower seed diets, respectively. The gross energy of the diets was 3911, 4425 and 4793 kcal/kg (dry matter basis) with 0, 25 and 50% sunflower seeds in the diet. Digestible energy increased linearly (P<.05) as the percentage of sunflower seeds in the diets increased from 0 to 50%. However, on close observation, a plateau in energy content can be seen at the 25 and

50% sunflower seed levels with values of 3192, 3499 and 3486 kcal/kg for 0, 25 and 50% sunflower seed diets, respectively. Apparent digestibility of energy for sunflower seed diets was reduced when compared to the control diet. However, total digestible energy of the sunflower seed diets increased due to their higher gross energy. Although the gross energy of the 50% sunflower seed diet was the highest, the reduced apparent digestibility of energy resulted in a digestible energy value approximately the same as for the 25% sunflower seed diet. Tribble et al. (1979) found that apparent digestibility of energy increased in sorghum-soybean meal diets containing 4 and 8% stabilized animal tallow compared to the control diet. The 8% tallow diet would be similar to the 25% sunflower seed diet in total fat content. The results reported by Tribble et al. (1979) are not in agreement with those reported herein. However, other factors such as the increased crude fiber of the sunflower diets may have affected these results. The added energy of the 50% sunflower seed diet was of no additional value compared to that of the 25% sunflower diet. Thus, as an energy source for sows, the 50% diet would not be recommended.

Apparent Digestibility of Ether Extract and Crude Fiber. Ether extract contents were 2.8, 11.85 and 20.20% (as fed basis) in diets containing 0, 25 and 50% sunflower seeds. Coefficients of apparent digestibility for ether extract had a linear and quadratic increase ($P<.01$) with values of 20.6, 64.9 and 68.1% for 0, 25 and 50% sunflower seed diets, respectively. These results are in agreement with those of Lowrey et al. (1962), Brooks (1967), Newman et al. (1967), Boenker

et al. (1969) and Kennelley and Aherne (1980) who reported ether extract digestibility increased with increasing levels of ether extract in the diets. None of these experiments utilized levels of ether extract as high as the 20.20% present in the 50% sunflower seed diet used in this experiment. The increased dietary ether extract of the 50% sunflower seed diet did not result in any significant change in ether extract digestibility over that of the 25% sunflower seed diet. Pigs were able to efficiently digest the fat in the 50% sunflower seed diet. However, the increased level of ether extract may have caused a decrease in apparent digestibility of crude fiber. Crude fiber contents of 2.3, 5.4 and 7.8% (as fed basis) had apparent digestibility coefficients of 24.1, 31.5 and 15.3% for 0, 25 and 50% sunflower seed diets, respectively. These values represent a linear and quadratic ($P<.05$) effect on crude fiber digestibility with the addition of sunflower seeds.

Newman et al. (1967) reported increased crude fiber digestibility with the addition of fat to the diet. However, Lowrey et al. (1962) and Brooks (1967) found no difference in digestibility of crude fiber due to fat addition in diets similar in ether extract content to the 25% sunflower seed diet used in this experiment. None of these experiments utilized ether extract levels as high as in the 50% sunflower seed diet. Ether extract levels this high may cause a decrease in the digestibility of the crude fiber as seen in the experiment reported herein. The decrease in digestibility of the crude fiber in the 50% sunflower seed diet cannot be specifically attributed to the increased levels of ether extract. Crude fiber levels in these diets also

increased with increasing levels of sunflower seeds. Cunningham et al. (1962), Pollmann et al. (1979), Kass et al. (1980) and Kennelley and Aherne (1980) have observed crude fiber digestibility to decrease in response to the extra dietary fiber when diets contained more than 10% crude fiber. Only limited research has been conducted to study changes in crude fiber digestibility in diets containing less than 10% crude fiber as used in this experiment. Therefore, the variation in crude fiber digestibility may be due to the crude fiber levels in the diet and cannot be specifically attributed to the ether extract levels.

Nitrogen Retention and Apparent Digestibility of Crude Protein. Apparent digestibility of crude protein approached linear significance with reduced coefficients for the 50% sunflower seed diet. Lowrey et al. (1962), Brooks (1967), Newman et al. (1967) and Tribble et al. (1979) reported no difference in crude protein digestibility in fat-added diets. Further research with higher levels of fat needs to be implemented in order to determine if increased fat levels reduce crude protein digestibility. Reduced values for crude protein digestibility may also be due to the increased fiber levels of the sunflower seed diets. Lloyd and Crampton (1955) and Whiting and Bezeau (1958) have reported increased crude fiber levels may affect crude protein digestibility.

Nitrogen retention was not significantly different among treatment groups. Boenker et al. (1969) and Kennelley and Aherne (1980) also reported nitrogen retention was not affected by supplemental dietary fat. It has been reported (Meyer, 1956; Whiting and Bezeau,

1958; Friend et al., 1963) that increasing the level of crude fiber in the diets of swine decreases nitrogen retention. The fiber levels in those diets were higher than the 7.8% crude fiber in the 50% sunflower seed diet. The level of crude fiber in this experiment may not have been high enough to cause decreased nitrogen retention.

Digestibilities of Nitrogen-free Extract, Organic Matter and Dry Matter. Linear and quadratic relationships were observed for the coefficients of apparent digestibility for nitrogen-free extract ($P<.01$), dry matter ($P<.05$) and organic matter ($P<.05$). In each of these criteria, a plateau occurred at the 0 and 25% sunflower seed level followed by a reduction in digestibilities for the 50% sunflower seed diet. Brooks (1967) and Newman et al. (1967) have reported the digestibility of nitrogen-free extract was not affected by adding fat to swine diets. The results of the experiment reported herein would agree with this conclusion when considering the 25% sunflower seed diet. However, reduced digestibility of nitrogen-free extract occurring in the 50% sunflower seed diet may be due to the higher ether extract content of that diet compared to the 25% sunflower seed diet and the fat-added diets used by Brooks (1967) and Newman et al. (1967). Nitrogen-free extract digestibility may also have been affected by the higher fiber content of the 50% sunflower seed diet.

Reduced dry matter digestibility in diets containing supplemental fat has been reported by Kennelley and Aherne (1980). The reduction in dry matter digestibility when the 50% sunflower seed diet was fed as

compared to the 25% sunflower seed diet is a reflection of the decrease in apparent digestibility of all components except ether extract.

SUMMARY AND CONCLUSIONS

This experiment consisted of three gestation-lactation trials and a digestion study conducted to investigate the effects of feeding diets containing 0, 25, and 50% ground, sunflower seeds to swine. All diets were formulated to contain recommended levels of crude protein, lysine, calcium and phosphorus.

The gestation-lactation trials involved a total of 99 sows and gilts fed the treatment diets from day 100 of gestation through 14 days of lactation. Increasing the level of sunflower seeds in the diet resulted in a significant linear increase in percent milk fat at 1 and 2 weeks of lactation. In all treatments, colostrum milk was lower in fat content than milk at 1 and 2 weeks of lactation. An analysis of the fatty acid composition of the milk from sows fed the treatment diets was performed. Milk percentage of linoleic acid increased and myristic, palmitic and palmitoleic acids decreased with increasing amounts of sunflower seeds in the diet, reflecting the concentration of these fatty acids in the sunflower seeds.

Sow weight loss and feed consumption during lactation, number of stillborn pigs, litter and piglet birth weights, litter and piglet 14-day weights, litter and piglet 14-day weight gains, number of piglets born and number of piglets weaned were not significantly different among treatments. Survival of piglets from dams fed the high-fat, sunflower seed diets was not significantly different from that of the controls.

Blood plasma glucose of piglets at birth and 24 hr of age was not significantly different among treatments. Plasma glucose at birth was significantly correlated with 24-hr glucose. However, only 3.6% of the variation in 24-hr plasma glucose concentration could be accounted for by plasma glucose at birth. Twenty-four-hr plasma glucose concentration was determined to be an accurate indicator of piglet survival to 14 days of age. Birth plasma glucose concentration was not a good indicator of survival to 14 days of age. Twenty-four-hr plasma glucose and birth weight were significantly correlated with 14-day weights of piglets.

The digestion study involved six barrows averaging 66 kg and fed diets containing 0, 25 and 50% sunflower seeds. Barrows were fed each diet once for a 6-day adjustment and a 6-day total collection period. The amount fed to each barrow was adjusted for consumption of the previous feeding so that barrows were allowed to consume near maximum intake without feed wastage. Data for one pig that became ill were omitted from the results.

Gross energies of the 0, 25 and 50% sunflower seed diets were 3911, 4425 and 4793 kcal per kilogram, respectively. There was a significant linear decrease in apparent digestibility of the energy in the diets with coefficients of 81.6, 79.1 and 72.7%, respectively. This resulted in digestible energy values of 3192, 3499 and 3486 kcal/kg for the 0, 25 and 50% sunflower seed diets, respectively. Although the gross energy of the 50% sunflower seed diet was the highest, the reduced apparent digestibility of the energy in this diet

resulted in a digestible energy value approximately the same as for the 25% diet.

A significant linear and quadratic increase in apparent digestibility of ether extract occurred with increasing sunflower seed content of the diets with a plateau at the 25 and 50% levels. Crude fiber apparent digestibility also responded with a linear and quadratic change with increasing levels of sunflower seeds.

Linear and quadratic relationships were observed for the coefficients of apparent digestibility for nitrogen-free extract, dry matter and organic matter. For each of these criteria, a plateau was observed at the 0 and 25% sunflower seed levels followed by a reduction in digestibilities for the 50% sunflower seed diet. No difference was observed in the apparent digestibility of crude protein or in the nitrogen retention of the diets.

In conclusion, there were no advantages for the addition of sunflower seeds to diets of late gestating and early lactating swine, with the possible exception of the additional fat found in the milk. Replacing part of the energy and protein in sow diets with 25% sunflower seeds had no adverse effect on sow or piglet performance. Therefore, sunflower seeds could be used as an alternative ingredient at this level in gestating and lactating diets. Because of the reduced digestibility of all components except ether extract in the 50% sunflower seed diet combined with the failure of some of the sows in the gestation-lactation trials to consume this diet, a 50% sunflower seed diet appears to have limited usefulness as a sow diet. Due to the problems

encountered with the 50% sunflower seed diet, the maximum level of sunflower seeds recommended in gestation-lactation diets appears to be between 25 and 50%.

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APPENDIX

TABLE 1. TRIAL AND PARITY LEAST SQUARES MEANS FOR 110-DAY GESTATION, POSTFARROWING AND 14-DAY LACTATION WEIGHTS, LACTATION WEIGHT LOSS AND LACTATION DAILY FEED CONSUMPTION

Item	Trial			Parity	
	1	2	3	Gilt	Sow
110-day gestation weight, kg[a]	208.8	228.8	244.9	202.8	248.1
Postfarrowing weight, kg[a]	194.2	205.1	226.2	186.6	230.4
14-day lactation weight, kg[a]	188.2	202.0	223.9	181.7	227.7
Lactation weight loss, kg[b]	1.7	3.7	7.4	5.5	3.1
Lactation daily feed consumption, kg[a]	4.38	3.38	3.99	3.75	4.09

[a] Trial and parity effect ($P<.05$).
[b] Trial effect ($P<.05$).

TABLE 2. TRIAL BY PARITY LEAST SQUARES MEANS FOR LACTATION WEIGHT LOSS AND LACTATION FEED CONSUMPTION

Trial	Parity	Lactation weight loss[a]	Lactation feed consumption[a]
1	Gilt	0	4.31
1	Sow	3.4	4.45
2	Gilt	9.2	2.95
2	Sow	+1.7	4.00
3	Gilt	7.3	4.00
3	Sow	7.5	3.95

[a] $P<.05$.

TABLE 3. TRIAL AND PARITY LEAST SQUARES MEANS FOR LIVE PIGS BORN AND STILLBORNS

Item	Trial			Parity	
	1	2	3	Gilt	Sow
Live pigs born[a,b]	8.8	9.3	11.1	9.2	10.3
Stillborn[a]	1.2	.97	.51	.84	.96

[a] Trial effect ($P<.05$).
[b] Parity effect ($P<.05$).

TABLE 4. LEAST SQUARES MEANS FOR TRIAL BY TREATMENT INTERACTION FOR STILLBORNS

Trial	Sunflower seeds, %	Stillborns[a]
1	0	1.90
1	25	.68
1	50	1.08
2	0	.45
2	25	1.42
2	50	1.05
3	0	.65
3	25	.45
3	50	.42

[a] $P<.05$.

TABLE 5. TRIAL AND PARITY LEAST SQUARES MEANS FOR LITTER AND PIGLET BIRTH WEIGHTS

Item	Trial			Parity	
	1	2	3	Gilt	Sow
Litter birth weight, g[a]	12,285	14,117	15,358	12,700	15,140
Piglet birth weight, g[b]	1,420	1,543	1,387	1,409	1,492

[a] Trial and parity effect ($P<.05$).
[b] Trial effect ($P<.05$).

TABLE 6. TRIAL LEAST SQUARES MEANS FOR BLOOD PLASMA GLUCOSE AT BIRTH

Trial	Birth plasma glucose mg/100 ml[a]
1	99.6
2	95.1
3	82.1

[a] $P<.05$.

TABLE 7. TRIAL LEAST SQUARES MEANS FOR COEFFICIENTS OF APPARENT DIGESTIBILITY OF DRY MATTER, NITROGEN-FREE EXTRACT AND CRUDE FIBER

Item digested	Trial		
	1	2	3
Dry matter[a]	77.95	80.53	77.95
Nitrogen-free extract[a]	88.00	89.15	86.83
Crude fiber[a]	19.23	32.34	19.41

[a] Trial effect ($P<.05$).

TABLE 8. MEAN SQUARES FOR 110-DAY GESTATION, POSTFARROWING AND 14-DAY LACTATION WEIGHTS, LACTATION WEIGHT LOSS AND LACTATION DAILY FEED CONSUMPTION

Source of variation	df	110-day gestation weight	Post-farrowing weight	df	14-day lactation weight	Lactation weight loss	df	Lactation feed consumption
Total	96			86			89	
Mean	1			1			1	
Treatment	2	705	524	2	1658	195	2	.28
Parity	1	99995**	93529**	1	90749**	261	1	5.16
Trial	2	22556**	18190*	2	18501**	482*	2	14.41
Trial x parity	2	5516	3549	2	1886	804**	2	3.93
Trial x treatment	4	288	122	4	687	58	4	.90
Parity x treatment	2	744	947	2	229	4.5	2	.31
Trial x parity x treatment	4	943	881	4	1343	88	4	.32
Error	78	2656	2430	68	1860	132	71	54.64

* P<.05.
** P<.01.

TABLE 9. MEAN SQUARES FOR STILLBORNS, LIVE PIGS BORN, LIVE PIGS AT 14 DAYS AND PERCENT SURVIVAL

Source of variation	df	Stillborns	Live pigs born	df	Live pigs at 14 days	Percent survival
Total	96			89		
Mean	1			1		
Treatment	2	.234	4.001	2	4.777	1.695
Parity	1	.362	29.791*	1	3.025	.515
Trial	2	4.090*	49.148**	2	7.750	3.161
Trial x parity	2	.036	7.689	2	4.022	2.176
Trial x treatment	4	3.085*	11.537	4	9.297	2.245
Parity x treatment	2	.638	12.031	2	2.542	1.628
Trial x parity x treatment	4	2.088	6.355	4	2.638	3.249
Error	78	1.193	5.375	70	4.826	3.334

* P<.05.
** P<.01.

TABLE 10. MEAN SQUARES FOR COLOSTRUM, 1-WEEK AND 2-WEEK MILK FAT PERCENTAGE

Source of variation	df	Colostrum milk fat	df	1-week milk fat	df	2-week milk fat
Total	96		88		87	
Mean	1		1		1	
Treatment	2	4.323	2	90.765***	2	110.105***
Parity	1	.389	1	.023	1	1.204
Trial	2	.579	2	1.085	2	1.922
Trial x parity	2	11.292	2	4.606	2	1.512
Trial x treatment	4	4.073	4	3.438	4	6.634
Parity x treatment	2	10.410	2	4.478	2	3.554
Trial x parity x treatment	4	2.323	4	.154	4	2.445
Error	78	5.871	70	2.797	69	2.736

*** P<.001.

TABLE 11. MEAN SQUARES FOR LITTER AND PIGLET BIRTH WEIGHT, 14-DAY WEIGHT AND 14-DAY WEIGHT GAIN

Source of variation	df	Litter birth weight	Piglet birth weight	df	Litter 14-day weight	df	Piglet 14-day weight	Litter 14-day weight gain	Piglet 14-day weight gain
Total	96			88		87			
Mean	1			1		1			
Treatment	2	2558	29.1	2	90830	2	134.8	51506	10.8
Parity	1	132215**	155.3	1	40880	1	248.7	1218	866.8
Trial	2	69585**	215.8*	2	55154	2	306.7	8897	273.2
Trial x parity	2	7484	60.7	2	82058	2	154.8	70280	223.0
Trail x treatment	4	18998	60.7	2	177658	4	573.7	86473	530.0
Parity x treatment	2	13526	43.1	2	29008	2	938.8	10134	690.0
Trial x parity x treatment	4	6885	81.1	4	60211	4	645.6	22625	340.9
Error	78	13746	56.0	70	91356	69	426.8	40167	414.8

* P<.05.
** P<.01.

TABLE 12. MEAN SQUARES FOR BIRTH PLASMA GLUCOSE AND BIRTH WEIGHT

Source of variation	df	Birth plasma glucose	df	Birth weight
Total	317		316	
Mean	1		1	
Treatment	2	248.8	2	36.6
Parity	1	58.3	1	330.4*
Trial	2	8120.4**	2	463.2**
Trial x parity	2	687.3	2	41.6
Trial x treatment	4	636.8	4	58.5
Parity x treatment	2	441.2	2	256.6*
Trial x parity x treatment	4	2399.9**	4	190.7*
Error	299	601.5	298	74.9

* P<.05.
** P<.01.

TABLE 13. MEAN SQUARES FOR 24-HR PLASMA GLUCOSE AND PIGLET 14-DAY WEIGHT

Source of variation	df	24-hr plasma glucose	df	14-day weight
Total	267		209	
Mean	1		1	
Trial	2	4931.3**	2	791.9
Treatment	2	644.2	2	1499.1
Trial x treatment	4	548.9	4	4610.2**
Parity	1	2243.5*	1	463.0
Trial x parity	2	2518.8*	2	1971.5
Treatment x parity	2	584.5	2	740.1
Trial x parity x treatment	4	2918.8	4	1631.0
Birth glucose	1	1794.9	1	11.2
Error	248	608.8	190	1076.2

* P<.05.
** P<.01.

TABLE 14. MEAN SQUARES FOR BIRTH AND 24-HR PLASMA GLUCOSE BY LIFE STATUS AT 14 DAYS

Source of variation	df	Birth glucose	df	24-hr glucose
Total	287		246	
Mean	1		1	
Live at 14 days	1	126.0	1	24644.6**
Error	285	704.4	244	584.4

** P<.01.

TABLE 15. MEAN SQUARES FOR COEFFICIENTS OF APPARENT DIGESTIBILITY OF THE PROXIMAL CONSTITUENTS AND ENERGY, PERCENT NITROGEN RETENTION AND DIGESTIBLE ENERGY OF THE DIETS

Source of variation	df	Dry matter	Crude protein	Energy	Ether extract	Nitrogen free-extract
Total	15					
Mean	1					
Trial	2	9.98*	9.29	8.89	87.94	6.07*
Treatment	2	107.32**	17.39	94.11**	3173.48**	31.57**
Trial x treatment	4	.96	4.42	2.88	89.70	.25
Error	6	1.51	3.46	7.84	43.97	.72

* P<.05.
** P<.01.

TABLE 15 CONTINUED

Source of variation	df	Organic matter	Crude fiber	Nitrogen retention	Digestible energy
Total	15				
Mean	1				
Trial	2	8.77	254.38*	37.20	15955
Treatment	2	124.59**	294.58*	36.19	136011*
Trial x treatment	4	1.19	7.23	8.15	5567
Error	6	1.74	31.39	12.19	17018